Fluctuation of *Fusarium* distribution in soil and the role of the forecrop in the control of *Fusarium* wilt of flax

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Abstract

The influence of crop rotation and wheather conditions on the *Fusarium* population in soil and on *Fusarium* wilt of flax was examined in the Institute of Native Natural Fibres in 1968-1975. The experiments were carried out in various regions of flax planting in Poland during 8 years. Crop rotation had a significant influence on the process of biological soil disinfection. *Fusarium* population in soil increased after planting flax, wheat, barley and sugar-beet, and decreased or did not change after rape, hemp, potato and leguminous plants. The crop rotation significantly influenced the composition of the *Fusarium* population as far as species are concerned. The highest wilt infection of flax was found in plantings after flax, sugar-beet and wheat and the weakest in plantings after rape. A six-year crop rotation was sufficient to eliminate the wilt pathogen from infested soil. But on flax-sick soil the process of biological disinfection proceeded more slowly and a seven-year interval between flax crops was too short.

INTRODUCTION AND LITERATURE REVIEW

Fusarium wilt is a serious threat to flax in Poland. The main source of infection is in the soil. *Fusarium* developing on flax may, after the vegetation season, continue to live in the soil in saprophytic state as mycelium and spores. Investigations on the surviving forms of these fungi in the soil were carried out by Buxton and Kendrick (1963) and Banihashemi and Dezeew (1973). The period of *Fusarium* survival in the soil was studied by Nash and Alexander (1965) and Kommendahl (1970).

A considerable accumulation of pathogens in the soil is one of the main causes of the phenomenon known as flax soil sickness (Kryn-

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ski and Zarzycka 1972). This occurs more and more frequently in regions where flax cropping is intensive, particularly in the south of Poland, and it is probably a result of flax planters tendency to reduce the intervals between successive flax plantings.

The persistence of *Fusarium* in the soil depends on the fungistatic or mycolytic activity of antagonistic soil microorganisms. The most important organisms of this type are *Actinomycetes* (Messiaen et al. 1965; Van der Spek 1965; Wnękowski 1966), bacteria (Messiaen et al. 1965; Strzelczyk 1966; Lemaire 1968) and some fungi, especially *Penicillium* (Kaufman and Williams 1965) and *Trichoderma* (Bisby et al. 1933; Fedorinčik 1968).

Investigations on the mechanisms of the antagonistic activity of these mikroorganisms towards various *Fusarium* species were performed by Meredith (1943), Messiaen et al. (1965), Strzelczyk (1966) and Lemaire (1968). The fluctuations of *Fusarium* distribution in the soil and composition of the antagonistic soil microflora are greatly affected by the plants cultivated in crop rotation, particularly those used as forecrop. Since besides the specialized *F. oxysporum* f. sp. *lini* there occur many other *Fusarium* species on flax such as *F. avenaceum*, *F. culmorum*, *F. equiseti* and *F. scirpi* (Czyżewska and Zarzycka 1968), the crop rotation may have an important influence both on the development of the antagonistic microflora and on the accumulation in the soil of polyphagous *Fusarium* species which may infect flax. The latter species remain on infected residues of other crops; for instance after wheat the population of *Fusarium culmorum* in soil increased (Garret 1946; Domsh et al. 1968), but the population of *Fusarium oxysporum* did not change (Ziling 1932). On the other hand, leaving the land fallow has a favourable influence on the development of the antagonistic microflora (Krassilnikov 1946).

Rataj (1954) considers the clover with grasses as a favourable forecrop before flax, Neafitava (1969) recommends clover, whereas Korneeva (1971) believes that clover increased the risk of flax infection with *Fusarium* wilt.

Investigations performed in Poland to date on the occurrence of flax soil-borne pathogens of the genus *Fusarium* (Zarzycka 1973) revealed the causes of the quantitative and qualitative variations in composition of *Fusarium* during 2 years after flax cultivation.

In the present studies it was attempted to establish the period necessary for biological disinfestation of the soil after flax planting and the influence of the crop rotation on this process.

The results may serve as guiding lines for establish of an appropriate crop rotation which is one of the elements of complex control of *Fusarium* wilt of flax.

Fig. Weather conditions during 1968-1974 years. Temperatures (1 — maximum, 2 — medium, 3 — minimum) and precipitations

Fig. Weather conditions during 1968-1974 years. Temperatures (1 — maximum, 2 — medium, 3 — minimum) and precipitations

MATERIAL AND METHODS

Investigations were undertaken in the Institute of Native Natural Fibres in 1968-1975 on the quantitative occurrence and specific composition of *Fusarium* on 9 fields in various regions of flax cultivation during its planting and in the subsequent 7 vegetation seasons at the following Experimental Stations:

1. Bukówka, Słupsk district, soil type: sandy-loamy podsol on heavy clay;
2. Kolnica, Suwałki district, soil type: podsol on boulder clay;
3. Pętkowo, Poznań district, soil type: black earth on sandy loam;
4. Sielec Stary, Leszno district, soil type: brown earth, loamy sand on clay;
5. Wojciechów, Częstochowa district, soil type: loamy-sandy podsollic soil on sand-gravel (3 fields were chosen here II, IV and Walce II).
6. Chylce, Warsaw district, soil type: podsol on clay loam (2 fields chosen: A and B). On field A flax was grown from 1961 to 1965, then oats, potatoes and again flax in 1968. The plantation was then infested with *Fusarium* wilt in 100 per cent. On field B, beginning with 1961 flax was cultivated for 2 years, then oats, potatoes, flax, oats, potatoes and flax in 1968, infestation in that year did not exceed 60 per cent.

The crop rotation on the chosen experimental fields during the period of experiments is given in Table 1.

In the year when flax was grown soil samples were taken from the rhizosphere for examination: in spring at the stage of flax seedlings and before shooting, and in summer in the period of blooming, a third sample was collected in autumn after the harvest from randomly chosen places on the field. In the following years soil samples were taken twice: in spring and in autumn from randomly chosen places on the field.

The quantitative occurrence and qualitative composition of *Fusarium* species in the soil samples was established by the modified method of successive dilutions described by Maciejowska (1967). The air-dry soil sample was mixed with potato dextrose agar with addition of 1 ppm Bengal rose and 1 ppm streptomycin sulphate. Dilutions of the order 10^{-4} , 10^{-6} , and 10^{-8} were poured into Petri dishes. The number of *Fusarium* colonies was counted after 7 days of incubation at 20-22°C.

The results were converted to 1 g of soil. On the basis of up-to-date observations less than 1000 fungus propagules in 1 g of soil was considered as a level not hazardous to flax plantations. *Fusarium* species were identified according to Booth's key (1971).

The pathogenicity of *F. oxysporum* f. sp. *lini* and other *Fusarium* species was tested in laboratory conditions by inoculating with spore

suspension 100 flax seedlings on filter paper cylinders in test tubes of 28×200 mm dimensions.

From the same soil samples fungi antagonistic to *Fusarium* spp. were also isolated. The antagonism of these organisms towards various species of the genus *Fusarium* was tested on Petri dishes on potato dextrose agar by measuring the growth inhibition zone.

Observations on the influence of the forecrop on flax infection with *Fusarium* wilt

The experiments were carried out in Wojciechów in 1970-1974 on podsolized sandy loam soil on a sand-gravel subsoil. The forecrops in 3 years preceding the experiments are shown in Table 3. In 1970-1972 the flax cultivar Milenium and in 1973-1974 the cultivar Fortuna were sown in the amount of 140 kg/ha. The experiments were conducted in 4 replications, the plot size were in 1970-1971 — 6 m² and in 1972-1974 — 10 m².

Observations on infection of the plants were made towards the end of the vegetation period in the stage of seed maturity, by counting the diseased and healthy plants in the middle rows of each plot.

RESULTS

Fusarium populations in the soil

In the soil samples taken from the rhizosphere of plants infected with *Fusarium* wilt the frequency of *Fusarium* spp. was very high, reaching 81 000 fungus propagules in 1 g of soil, whereas in samples of soil collected after the flax harvest it was much lower (Table 1).

In the subsequent years after flax planting the *Fusarium* population in the soil markedly decreased showing sometimes seasonal fluctuations: a decrease in spring and increase in autumn. The decrease in the frequency of *Fusarium* in the soil was noted on many fields after the winter periods 1968-1969 and 1969-1970 and in Pętkowo and Bukówka in 1971-1972. This was clearly associated with weather conditions: severe frost with relatively low precipitation. An increase in the frequency of *Fusarium* spp. was noted in the vegetative season in the years 1969, 1970 and in some cases in 1971 (Bukówka and Pętkowo) and in 1972 (Wojciechów and Kolnica). It was usually connected with high precipitation and moderate air temperature about 20°C.

In general the frequency of *Fusarium* in the soil decreased to a level which would not threaten flax crop in course of 5-year period after flax cultivation in Pętkowo, Bukówka, Kolnica and on fields II and IV in Wojciechów. On the other hand in the soil of Chylice and

Sielec Stary the *Fusarium* population in the soil was still very high in 5-6 years after the flax culture was ceased.

The plants grown in the crop rotation were greatly influencing the state of soil infestation with *Fusarium*. A distinct increase of its occurrence in the soil was noted after flax and sugar-beet plantings and after some cereals such as wheat and barley.

After cultivation of leguminous crops, mixture of cereal and leguminous crops, potatoes and hemp the frequency of *Fusarium* occurrence in the soil varied only slightly, while after rape and cereals like rye, oats and maize it showed a marked decreasing tendency (Table 1).

The spectrum of *Fusarium* species isolated from the soil was rather varied (Table 2). *F. oxysporum* Schl. and *F. o. f. sp. lini* (Bolley) Snyder et Hans. was most numerously represented. The frequency of the latter species decreased gradually during the 8 years of study. In last years of experiment it was being found in soil samples only sporadically. The frequency of *F. o. f. sp. lini* also decreased and in the last samples collected in Kolnica, Pętkowo and Sielec Stary this form was not detected at all. On the other hand, in the latest samples from flax-sick soils in Chylice and Wojciechów a high soil infestation with this species was noted.

F. equiseti (Corda) Sacc. was very common. Its frequency diminished, but not regularly could be found in these fluctuations. *F. solani* (Mart.) Sacc. was more frequently detected after cereals, potatoes, beets and leguminous crops. *F. culmorum* (W. G. Smith) Sacc. was rather rare and found mostly on fields where cereals had been grown. The sporadic occurrence of *F. avenaceum* (Corda ex Fr.) Sacc. was connected with maize and cereals plantations. *F. sambucinum* Fuckel also occurred sporadically.

Species of the genus *Penicillium* and *Trichoderma* were isolated as representatives of the antagonistic fungi. In soil samples collected in the first years of investigation various species of *Penicillium* prevailed. The level of their occurrence varied within the range of 5 to 40 thousands of fungi propagules in 1 g of soil. *Trichoderma* prevailed in the soil samples of the 5th and 6th year following flax plantings. Their occurrence varied within the limits of 1 to 25 thousands of fungi propagules in 1 g of soil. The number of antagonistic fungi increased after leguminous crops.

Influence of forecrop on infestation of flax with *Fusarium* wilt

Of all the forecrop sequences applied most favourable seems to be the 3 years' set: peas in first year, then green fodder clover and winter rape directly before flax as was shown in 1973 in experiment I

Table 1

The influence of crop rotation on *Fusarium* soil infection during flax planting and in the next seven years

Occurrence of fungus propagules in 1 g of soil (in thousands)										
Year of soil sampling	Chylce					Wojciechów				
	Bukówka	field A		field B	Kolnica	Pętkowo	Sielec Stary	field Walce II	field II	field IV
1968	spring	20.00	—	—	—	8.50	27.50	81.70	—	—
	summer	30.00	15.77	26.42	36.00	60.00	35.00	25.00	21.70	4.17
	autumn	5.65	28.86	16.95	46.24	3.07	2.01	21.09	8.72	0.46
1969	spring	3.82	15.39	7.28	12.49	1.98	13.25	1.29	1.71	1.06
	autumn	8.55	12.48	8.64	1.17	2.79	19.24	8.24	5.19	1.06
1970	spring	18.84	5.40	4.98	2.92	0.33	2.89	0.85	0.17	0.12
	autumn	1.34	5.04	4.45	4.57	1.81	5.72	2.86	3.57	2.89
1971	spring	1.39	5.67	5.87	—	2.93	5.28	3.21	4.38	2.00
	autumn	3.45	4.22	4.36	1.01	4.21	5.61	3.62	2.50	0.98
1972	spring	1.88	30.85	6.35	7.94	1.67	5.84	4.62	4.28	1.02
	autumn	1.67	1.78	5.32	0.08	1.80	3.65	9.38	5.36	2.50
1973	spring	1.05	3.75	4.00	0.01	0.87	3.67	1.15	0.88	0.87
	autumn	0.83	3.67	7.53	0.08	0.05	8.37	0.88	0.84	0.83
1974	spring	0.15	1.08	0.69	0.00	0.34	8.64	0.99	0.29	0.08
	autumn	0.38	2.04	0.91	0.02	1.25	4.15	1.92	0.50	0.23
1975	spring	0.17	6.25	3.32	0.01	0.47	1.22	1.14	0.42	0.09

Crop rotation

1968	flax	flax	flax	flax	flax	flax	flax	flax	flax	flax	flax	flax
1969	wheat	rape	oat	oat	flax	wheat	wheat	wheat	sugar-beet	wheat	potato	potato
1970	maize	rye	rye	rye	potato	barley	barley	beet	wheat	barley,	flax	flax
										leguminous	crops	
1971	wheat	rape	rape	rape	potato	corn legu- minous crops mixture	leguminous crops	flax	flax	sugar-beet	wheat	wheat
1972	wheat	oat	oat	oat	barley	flax	rape	wheat	wheat	alfalfa	seed beet	seed beet
1973	rye	wheat	wheat	wheat	red clover	wheat	sugar-beet	wheat	wheat	potato	hemp	hemp
1974	flax	leguminous crops	leguminous crops	leguminous crops	wheat	sugar-beet	flax	rye grass	seed	beet	hemp	hemp

Table 2
The species of *Fusarium* in soil from different tested fields

Locality	Year of soil sampling	Frequency of <i>Fusarium</i> species						
		<i>F. oxysporum</i>	<i>F. oxysporum</i> f. <i>sp. lini</i>	<i>F. equiseti</i>	<i>F. culmorum</i>	<i>F. sambucinum</i>	<i>F. avenaceum</i>	<i>F. solani</i>
1	2	3	4	5	6	7	8	9
Bukówka	1968 spring	++	++++					
	summer	++	++++	++				
	autumn	+	++					
	1969 spring	+	++	+	+			
	autumn	++	+++					
	1970 spring	++++	+++	+	+		+	
	autumn	+	++					
	1971 spring	+	++	+				
	autumn	++	+					
	1972 spring	+	+	+				
	autumn	+	++					
	1973 spring	+	+					
	autumn	+		+				
	1974 spring	+						
	autumn	+						
Chylice field A	1975 spring	+		+	+			
	1968 summer	++	++++	++				
	summer	++	++++	++		+	+	
	1969 spring	++	++++	+				
	autumn	+	+++	++				+++
	1970 spring	+	++	+			+	
	autumn	+	+	++				
	1971 spring	+	+	+				+
	autumn	+	+	++				
	1972 spring	+	++++	++	+			+
	autumn	+	+	+				
	1973 spring	+	++	+				
	autumn	+	++	+				+
	1974 spring	+	+					
	autumn	+	+					
Chylice field B	1975 spring	++	+	+				
	1968 summer	++	++++	+				
	autumn	+++	+++	++				
	1969 spring	+	++	++	+		+	+
	autumn	+	+++	+++	+			
	1970 spring	+	++	++				
	autumn	+	++	+			+	+

	1	2	3	4	5	6	7	8	9
Chylice field B	1971 spring	+	++	+					
	autumn	+	++	++					
	1972 spring	++	++						
	autumn	+	++	+					
	1973 spring	+	++	+					
	autumn	++	++					+	
	1974 spring	+	+	+					
	autumn	+	+						
	1975 spring	++	+	+					
	1968 summer	+++	+++	++++	++	++			
Kolnica	autumn	+++	++++	+++			++		
	1969 spring	++	++	+++		+			
	autumn	+	+	+				+	
	1970 spring	+	+	+	++			+	
	autumn	+		++	+				
	1971 spring								
	autumn	+		+	+				
	1972 summer	++	+	++	++			+	
	autumn	+		+					
	1973 spring	+		+					
Pętkowo	autumn	+		+					
	1974 spring	+		+					
	autumn	+		+					
	1975 spring			+					
	1968 spring			++	++		+	++	
	summer	++	++++	++++	++	+++		+++	
	autumn	+	+	++	+	+			
	1969 autumn	+	+	+	+				
	spring	+	+	++	+			+	
	1970 autumn	+	+	+					
Sielec Stary	spring	+	+	+					
	1971 spring	+	+	+				+	
	autumn	++	+	++					
	1972 spring	+	+	+				+	
	autumn	+	++	+					
	1973 spring		+			+			
	autumn	+	+		+				
	1974 spring	+	+	+					
	autumn	+	+	+					
	1975 spring	+	+	+					
Sielec Stary	1968 spring	++	++++	++++	+++				
	summer	++	+++	++++					
	autumn	+	+	++		+			
	1969 spring	+	++	++++				+	
	autumn	++	+++	+++	+				

	1	2	3	4	5	6	7	8	9
Sielec	1970	spring	+	+	+			+	
		autumn		+	++			+	
Sławy	1971	spring	++	+	++				
		autumn	++	+	++		+		
	1972	spring	++	+	+			++	
		autumn	++	+	+				
	1973	spring	++	+	+	+			
		autumn	++	+	++				
	1974	autumn	++	+	++				
		spring	+	++	+				
	1975	spring	+	+					
	1968	summer	+	+++	+++		+		
		autumn	+	++	++				
Woj-	1969	spring	+	+	+				
		autumn	++	+	++	+		++	
ciechów	1970	spring	+	+	+				
		autumn	+	+	++				
field II	1971	spring	+	++	+			++	
		autumn	+	+	+				
	1972	spring	++	+	+				
		autumn	++	+	+			+	
	1973	spring	+	+	+				
		autumn	+	+				+	
	1974	spring	+	+				+	
		autumn	+		+				
	1975	spring	+		+				
	1968	spring	++++	++++	++++		++	+	+
		summer	++++	++++	+				
		autumn	++	++++	++		++		
Woj-	1969	spring	+	++	+				
		autumn	++	++	+			+	
ciechów	1970	spring	+	+	+				
		autumn	++	+	+	+			
field	1971	spring	+	++	+	+			
		autumn		++	++				
	1972	spring	+	++	+				
		autumn	++	++	++	+		+	
Walce II	1973	spring	+	+		+		+	
		autumn	+	+	+	+			
	1974	spring	+	+	+				
		autumn	+	+	+				
	1975	spring	+	+	+				

	1	2	3	4	5	6	7	8	9
Wojciechów field IV	1968 summer	+++	+++	+					
	autumn	+	+	+		+	+		
	1969 spring	+	+	+					
	autumn	+	+	+					
	1970 spring	+	+	+					
	autumn	+	++	+					
	1971 spring	+	++						
	autumn	+	+	+					
	1972 spring	+	+	+					
	autumn	+	+	+					
	1973 spring	+		+					
	autumn	+		+					
	1974 spring	+		+					
	autumn			+					
	1975 spring			+					

Note: **** very high occurrence of *Fusarium* species: more than 10 000 fungus propagules in 1 g of soil,

*** high occurrence of *Fusarium* species: 5 000-10 000 fungus propagules in 1 g of soil,

** medium occurrence of *Fusarium* species: 1 000-5 000 fungus propagules in 1 g of soil,

* low occurrence of *Fusarium* species: less than 1 000 fungus propagules in 1 g of soil.

Table 3

The influence of three—years forecrops on *Fusarium* wilt of flax in Wojciechów (1970-1974)

Years	Forecrops previous to flax			Percentage of infected plants in seed maturity stage
	3rd year ahead	2nd year ahead	1 year ahead	
1970	flax	winter wheat	sugar-beet	48.8
1971	green fodder alfalfa	rape	sugar-beet	36.0
1972	rape	sugar beet	flax	73.2
1973 I	pea	green fodder clover	winter rape	12.0
1973 II	spring barley with alfalfa	alfalfa	flax	59.1
1974	hemp	winter wheat	sugar-beet	27.5

(Table 3). In this experiment flax infection with *Fusarium* wilt was low, not exceeding 12 per cent, although the weather conditions favoured infection (dry weather between June and July and temperature exceeding 25°C). In experiment II in the same year where the immediate forecrop was flax, infection of the plants reached almost 60 per cent. The least favourable seems to be crop rotation used in 1972: rape, sugar-beet and flax. Infection of the plants exceeded 73 per cent. The weather conditions in that year favoured infection (dry weather in the beginning of June and of July and rather high temperatures). When sugar-beet was the immediate forecrop as in 1970, 1971 and 1974 the per cent of plants infected with *Fusarium* wilt depended on the weather conditions and varied from 27,5 per cent in 1974 when these conditions were unfavourable to disease development (high humidity and relatively low temperature) to 48,8 per cent in 1970 when the weather favoured spread of *Fusarium* wilt.

DISCUSSION

The frequency of *Fusarium* in the soil is the result of two processes: multiplication and spread of the fungus which can live in saprophytic form on residues of organic matter in the soil on the one hand and of the mycolytic and fungistatic activity of antagonistic soil microorganisms on the other hand. Hence even a high level of *Fusarium* spp. in the soil in the period of flax cultivation does not mean this soil is strongly and above all durably infested. Thus, in spite of high soil contamination during flax cultivation in Kolnica, 4 years later the frequency of *Fusarium* spp. decreased considerably, and the level of *F. oxysporum* f. sp. *lini* fell to zero. This indicates a weak spreading ability of *Fusarium* spp. in the soil and good conditions for the development of antagonistic microorganisms. Moreover, the weather conditions in this region do not favour the development of *Fusarium* wilt. This is in agreement with the local observations on this disease. *Fusarium* wilt of flax is no problem in Kolnica.

On the other hand, on the flax-sick fields in Chylice strongly infested with *Fusarium*, the process of biological disinfection proceeded very slowly. This is connected both with the high accumulation of the pathogens in the soil and with the poor development of the antagonistic microflora.

The process of biological soil disinfection is influenced by many factors such as type of soil, kind and doses of fertilizers applied, plants grown as forecrop and weather conditions. All these factors affect both the fungi ability to spread in the soil and to survive and the development of antagonistic soil microflora. The experiments on soil infestation

with *Fusarium* have shown that the factor decisive for the frequency of *Fusarium* occurrence in the soil and the change of *Fusarium* wilt of flax was the crop rotation and particularly the forecrop. Too frequent planting of flax on the same field, as was the case in Chylice and Wojciechów, led to a high accumulation of the pathogen in the soil and caused weaker ability of biological soil disinfestation. According to the data of the Progress Report (1950) a 5-year interval in flax cultivation with the application of suitable crop rotation was sufficient to eliminate the risk of *Fusarium* wilt infection, and after a 7-year interval the high yield of flax fibre was obtained.

In the present investigations a 5-year interval between flax crop ensured soil disinfestation only in the case of "healthy" soil with a high population of microorganisms antagonistic to *Fusarium*. In flax-sick soil in which large quantities of the wilt pathogen were accumulated, the process of biological disinfestation was much slower, probably owing to the weaker development of the antagonistic organisms, and then even a 7-year crop rotation proved too short.

The plants grown in crop rotation, particularly as forecrop considerably influence the level of *Fusarium* in the soil and the risk of flax infection with wilt. It should be stressed here that no data for the Polish conditions were available, and the literature data are scarce and frequently controversial. Therefore the present experiments were treated as preliminary. In view of this, soil was examined from fields with a crop rotation normally applied in the given farm. In further investigations in progress in the Institute of Native Natural Fibres the crop sequence is established according to a plan based on the results of up-to-date studies.

Flax is the most unfavourable forecrop of all examined crops, as was shown in investigation on the level of *Fusarium* in the soil and observations on plant infection. The unfavourable forecrops for flax from the phytopathological point of view are some cereals such as wheat and barley, after cultivation of which the level of *Fusarium* in the soil rises as a rule. A high infection of flax grown after wheat was also observed. When oats and rye were sown as a forecrop the amount of *Fusarium* in the soil decreased. The literature data do not completely agree with the results presently obtained. Marchionatto (1954) considers that wheat and maize had a favourable influence, reducing the risk of *Fusarium* wilt of flax, and Rataj (1954) and Neafitava (1969) observed a higher infection on flax planted after rye.

Sugar-beet should be classed as a next unfavourable forecrop, which arised as a result of experiments on soil infestation and plant infection.

Leguminous crops particularly clover may be considered as a good

forecrop, since after their cultivation *Fusarium* infestation did not increase and frequently even decreased. The use of clover as forecrop is controversial: Neafitava (1969) observed a lower infection of flax planted after clover, whereas Korneeva (1971) believes that clover cultivation enhances the chance of flax infection with *Fusarium* wilt. According to the data of the Progress Report (1950), clover and grasses had a favourable effect on the process of biological disinfestation and reduced the risk of flax infection with *F. oxysporum* f. sp. *lini*.

In the present experiments cultivation of a mixture of leguminous and cereal plants increased the *Fusarium* level in the soil, but flax planted after them was relatively little infected. On the other hand, Rataj (1954) considers such mixtures as favourable to biological soil disinfestation.

Rape and potatoes belong to plants which as forecrop lowered the frequency of *Fusarium* occurrence in the soil. Flax planted directly after these plants was little infected with wilt. No information is found in the available literature about rape as a forecrop, whereas after potatoes Neafitava (1969) observed a relatively high infection of flax with *Fusarium*.

Fertilization influences the process of biological soil disinfestation however, since the choice of fertilizers and their doses were strictly bound with the kind of crop planted, it is difficult to separate these problems. Since Timonin (1940) affirms that the level of *F. oxysporum* f. sp. *lini* is influenced more by the crop planted than by the intensity of fertilization, attention was mainly devoted, when considering these problems, to the plants included in crop rotation.

Weather conditions play an important role in the occurrence of *Fusarium* in the soil and the chance of flax infection with *Fusarium* wilt. Fungi of the genus *Fusarium*, particularly *F. oxysporum* have relatively high temperature requirements. As observed in the experiments, the fungi developed in the soil best about 20°C with relatively high rainfall. On the other hand, low temperature, frost and dry weather had an unfavourable influence on *Fusarium* occurrence in the soil. This may probably explain the phenomenon that on fields in the northern regions of the country the process of biological disinfestation was much quicker than in central or southern Poland.

It should be mentioned, however, that the risk of flax infection with *Fusarium* wilt does not solely depend on the degree of accumulation of the pathogen in the soil, but also on conditions favouring infection. *Fusarium* wilt infects flax most intensively usually after a period of dry weather and high air temperature, which lower the resistance of plants and favour the wilt infection. Since such conditions

prevail more frequently in the southern regions of flax plantation than in the northern ones, therefore in Sielec Stary or Wojciechów the risk of flax infection is much higher than in Bukówka or Kolnica, even if the level of pathogen population in the soil is the same.

With progressing concentration and intensification of flax production exceptionally favourable conditions arise for more and more frequent flax-sickness of the soil, particularly in the southern regions. Therefore attention should be paid to the necessity of a long interval between flax plantings and the cultivation of appropriate forecrops.

CONCLUSIONS

1. The degree of soil infestation with *Fusarium*, high during flax cultivation decreased gradually over the 7 years of observation.

2. The process of biological soil disinfection was faster on "healthy" than on flax-sick soils. On the former a 5-year interval in flax cultivation was sufficient.

3. For soil brought by too frequent flax cultivation to a state of flax-sickness a 7-year interval between the flax plantings was too short.

4. The forecrop for flax influenced the fluctuation of *Fusarium* distribution in the soil:

a. the frequency of *Fusarium* population in soil and infection of flax with *Fusarium* wilt increased after flax, wheat, barley and sugar-beet,

b. the frequency of *Fusarium* population in soil decreased or did not change and the flax was rarely infected with *Fusarium* wilt after leguminous crops, rape, hemp, potatoes, rye oats and maize.

5. The level of *Fusarium* population in the soil was affected by weather conditions. The pathogen developed best at an air temperature of about 20°C with high air humidity, whereas frost and dry weather limited the development of *Fusarium*.

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Fluktuacje w zasiedlaniu gleby przez grzyby z rodzaju *Fusarium* i rola przedplonu w walce z fuzariozą lnu

Streszczenie

W Instytucie Krajowych Włókien Naturalnych w latach 1968-1975 badano wpływ płodozmianu i warunków atmosferycznych na zasiedlenie gleby przez grzyby z rodzaju *Fusarium* i na porażenie lnu przez fuzariozę.

Badania przeprowadzano w ciągu 8 lat w różnych rejonach uprawy lnu w Polsce. Zmianowanie miało wyraźny wpływ na proces biologicznego oczyszczenia gleby. Stopień zasiedlenia gleby przez grzyby z rodzaju *Fusarium* wzrastał po uprawie lnu, pszenicy, jęczmienia i buraków cukrowych, a spadał lub nie ulegał zmianie po rzepaku, konopiach, ziemniakach i roślinach motylkowych. Zmianowanie miało wpływ na skład gatunkowy *Fusarium* spp. w glebie. Najsilniejsze porażenie roślin obserwowano po lnie, burakach cukrowych i pszenicy, a najslabsze po rzepaku. Na ogół 6-letnia przerwa między jedną uprawą lnu a drugą była wystarczająca, aby zmniejszyć populację grzybów z rodzaju *Fusarium* w glebie do poziomu nie stanowiącego zagrożenia dla plantacji lnu. Leczą na glebach wyniały proces biologicznego oczyszczania przebiegał wolno i nawet 7-letnia przerwa między uprawami lnu okazała się zbyt krótka.